TECHNICAL DATA

5100A / 5110A FREQUENCY SYNTHESIZER

Revised 4/14/64

Features:

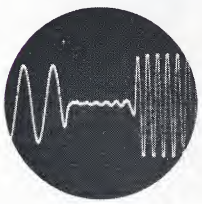
- 5 billion discrete signals, DC to 50 Mc
- Remote programming—1 millisecond switching speed
- Frequency increments from 0.01 cps to 10 Mc
- Search oscillator lends additional versatility
- High stability—all signals derived from single quartz oscillator
- Spectral purity—spurious signals 90 db down
- Solid-state, modular construction

Applications:

- Extremely broad range of applications, including
- Automatic testing of frequency sensitive devices
- Spectroscopy—excitation and reference source
- Communications and telemetry
- Doppler tracking
- Radar

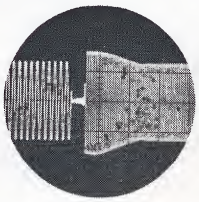
These photographs show high speed switching capability:

100 to 300 Kc 300 Kc



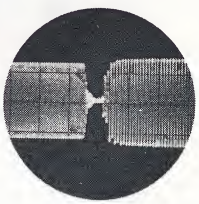
10 μs/cm Sweep Time

100 to 300 Kc



50 μs/cm Sweep Time

3 to 1 Mc



10 μs/cm Sweep Time

Dead time and transients are well within the 1 millisecond specification

5100A EEM 2900

COMPLETE COVERAGE IN ELECTRONIC MEASURING EQUIPMENT

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Description

The Hewlett-Packard Model 5100A/5110A Frequency Synthesizer provides any output frequency from 0.01 cps to 50 Mc, selectable in steps as small as 0.01 cps. The output frequency is derived from a precision single frequency source through direct synthesis, a technique which translates the stability and spectral purity of the source to the selected output. A precision quartz oscillator of extreme stability is provided, or an external 1 Mc or 5 Mc standard may be used.

Particular care has been exercised in the design of the Model 5100A/5110A to insure that a very clean output signal is provided over the entire frequency range. A high order of spectral purity is essential for accurate doppler measurements, microwave spectroscopy, narrow band telemetry or communications, and similar applications. The design and construction of the Hewlett-Packard Frequency Synthesizer make it possible to obtain output signals with a spurious content at least 90 db below the selected output.

The 5110A Synthesizer Driver generates 22 spectrally pure signals from the standard signal. These 22 frequencies are then fed to the 5100A Frequency Synthesizer by means of rear panel BNC connectors (Figure 1), and are continuously available. The variable output signal is synthesized from these fixed frequencies by a series of arithmetic operations.

Since no phase-locked loops are involved, switching from one output frequency to another can be accomplished very rapidly, either from the front panel push-buttons or remotely. Less than one millisecond is required to change output frequency. For applications requiring rapid frequency selection, Model 5100A/5110A is arranged for remote programming through rear connectors.

Operational Features

Remote Programming—Less than one millisecond switching time offers control flexibility never before possible.

Any frequency or search oscillator position that can be selected by front panel push-buttons may also be remotely selected. Three fifty-pin connectors located on the 5100A rear panel (Figure 1) provide pins corresponding to each front panel push-button position, a ground connection, and a — 12.6 volt line for use in remote programming. The — 12.6 volts is available in two arrangements—continuous and switched (present when REMOTE mode is selected at front panel). This lends additional versatility since it enables the use of a combination of remote and local programming.

An actual contact closure such as a relay is not required for remote programming of the Synthesizer. The required — 12.6 volts DC may be applied to the selected pin electronically.

Figure 2 is representative of one of the many applications made possible by the Synthesizer's remote programming capability. This plot of the response of a single sideband crystal filter was obtained by programming the Synthesizer to generate frequencies in a variety of incremental steps. Less than one minute was required for the complete plot.

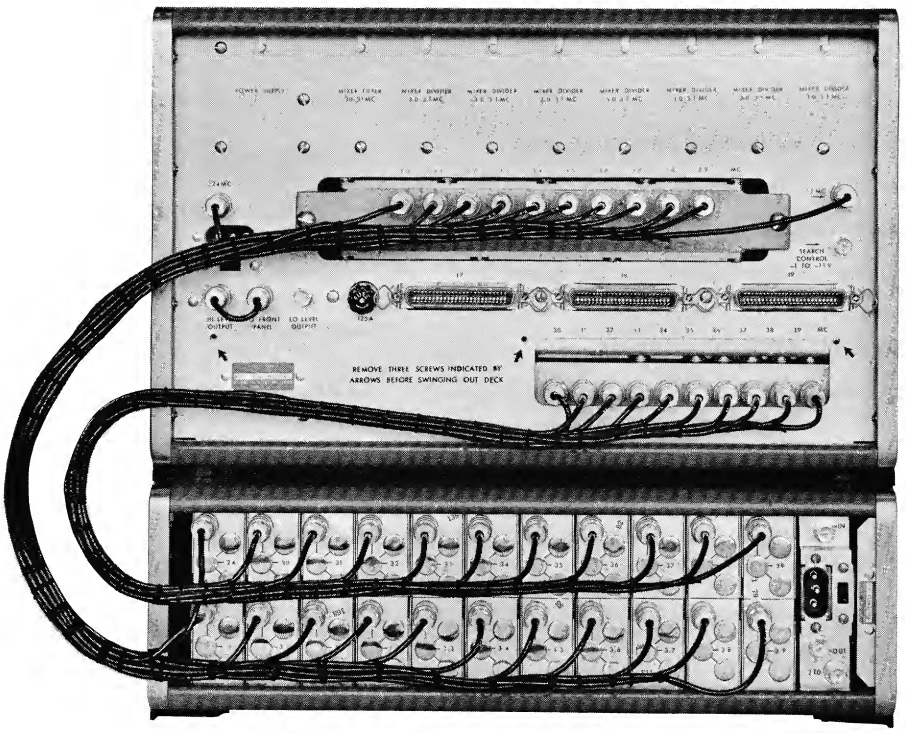


Figure 1

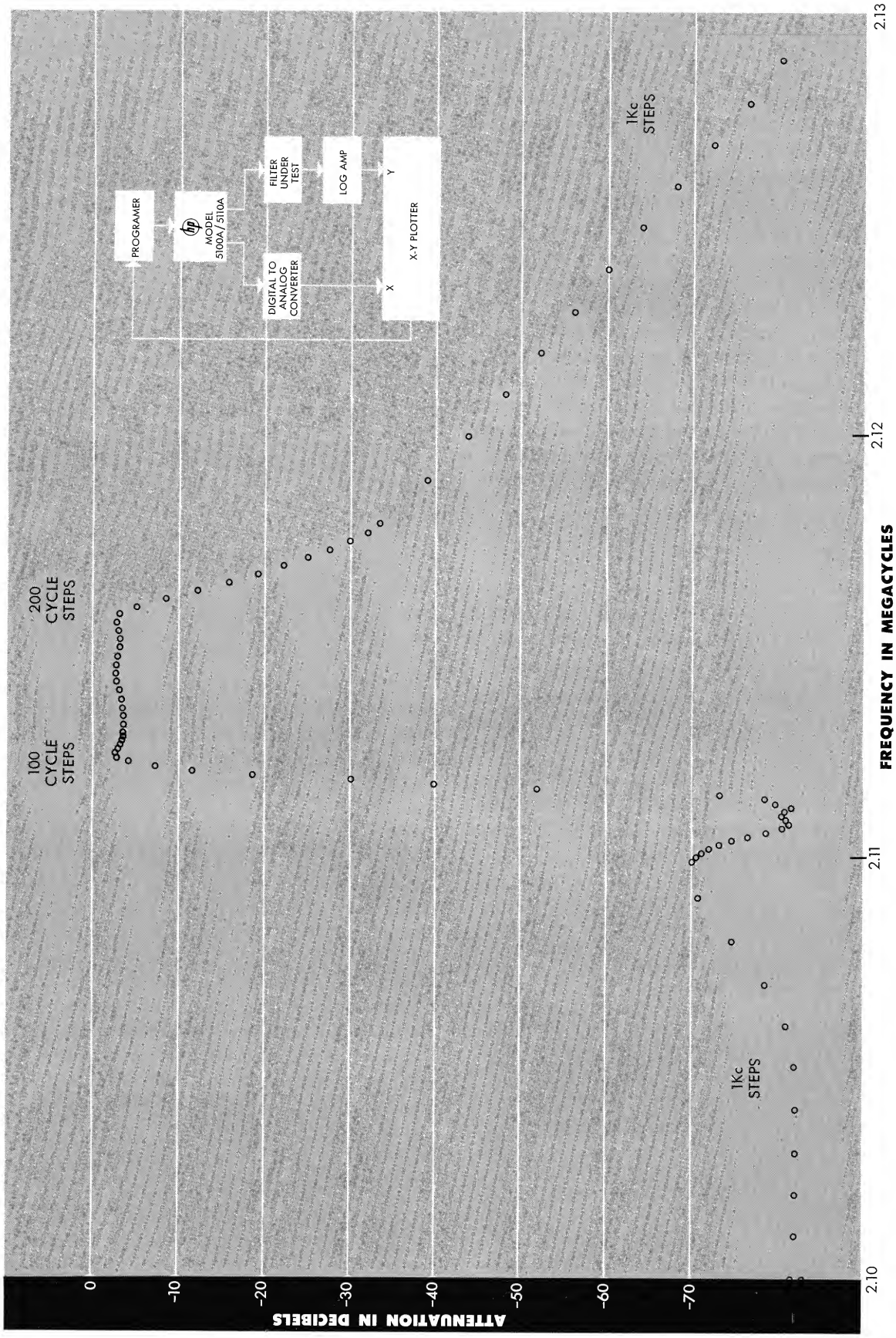

100 CYCLE STEPS
200 CYCLE STEPS
1Kc STEPS
1Kc STEPS
PROGRAMER
MODEL 5100A/5110A
DIGITAL TO ANALOG CONVERTER
FILTER UNDER TEST
LOG AMP
X
Y
X-Y PLOTTER
0
-10
-20
-30
-40
-50
-60
-70
ATTENUATION IN DECIBELS
2.10
2.11
2.12
2.13
FREQUENCY IN MEGACYCLES

Figure 2

The Search Oscillator

Continuous Tuning and Sweep Capability Add Versatility

The search oscillator is an L-C oscillator which allows the operator to continuously "search" any significant column from 100 kc to 0.01 cps, either manually by front panel dial or remotely by application of a suitable DC voltage. The typical voltage vs. frequency characteristic is shown in Figure 3. The approximate slope is 100 kc/volt.

If the search oscillator is used, the stability of the Synthesizer output is determined by either that of the standard instrument or that of the search oscillator—whichever is worse. The search oscillator has a root-mean-square deviation of approximately 1 cycle (one second average) if used in the most significant column that can be searched (100 kc steps). This Δf_{rms} is reduced by a factor of 10 for each less significant column that is searched. As an example, consider that the search oscillator is used in the 10 kc column, at an output frequency in the 10 Mc region. The instability in the output frequency due to the search oscillator is then:

$$\frac{\Delta f_{rms}}{f_{out}} = \frac{\pm\ 0.1\ \text{cps}}{10 \times 10^6\ \text{cps}} = \pm\ 1 \times 10^{-8}$$

At this output frequency, and using one second averaging, the short term stability of the Synthesizer itself is on the order of $\pm\ 3 \times 10^{-11}$. Consequently, the search oscillator governs in this case.

The plots displayed in Figures 4, 5, 6, and 7 are representative of the impressive versatility of the hp Frequency Synthesizer. The microwave spectral lines of Cs^{133} were obtained using the system shown in Figure 4.

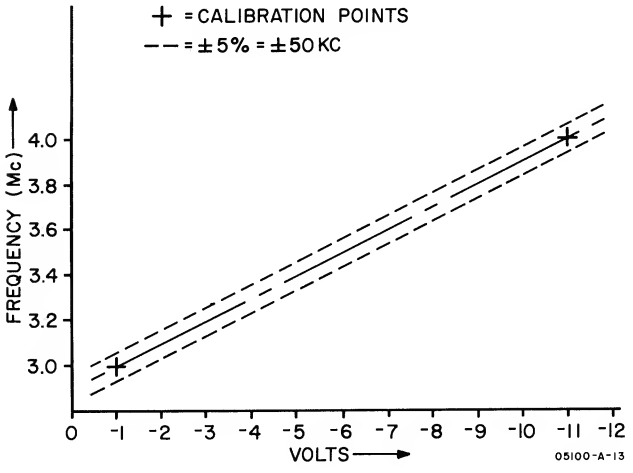


Figure 3

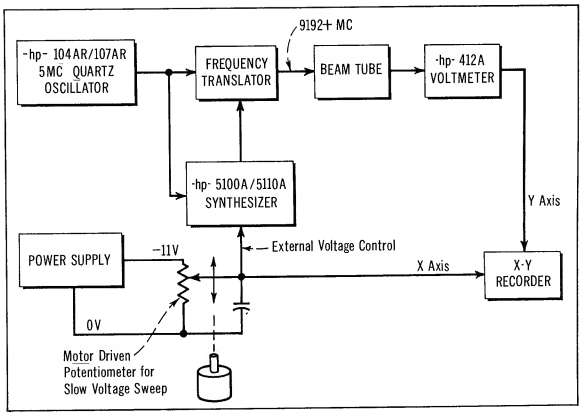


Figure 4

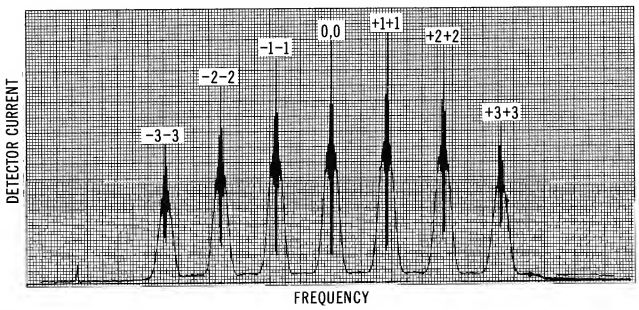


Figure 5

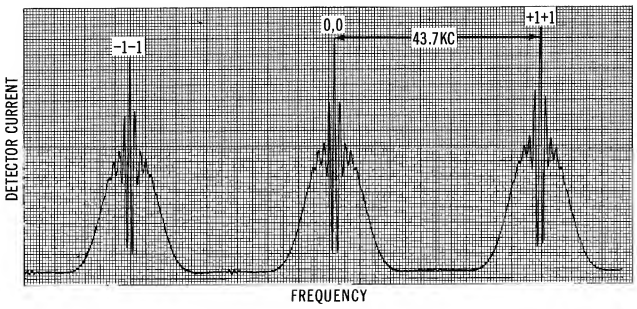


Figure 6

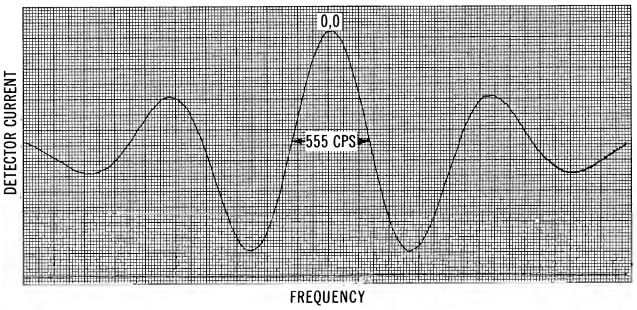


Figure 7

The frequency translator adds the Synthesizer output to a fixed harmonic of the stable 5 Mc source to provide an excitation frequency of 9192+ Mc. A desired significant column of the Synthesizer output is continuously swept by employing the external voltage control feature of the Synthesizer's search oscillator. The three plots were obtained by searching successively less significant columns. This type of system greatly simplifies the investigation of the homogeneity of the small magnetic field used in the region where Cesium hyperfine transitions occur. For further details see the Hewlett-Packard Journal, Vol. 15, No. 4, December, 1963.

Spectral Purity and Short Term Stability

Many applications require that a signal be multiplied into the microwave region. If the frequency multiplying device is broadband, the ratio of total sideband power to signal power increases as the square of the multiplying factor. Since the total power in a frequency modulated wave is constant, the increased sideband power must come from the carrier. The spectrum of the signal begins to "spread" since the increased sideband amplitude causes the intermodulation between sidebands to become appreciable. It is desirable, then, that the original signal have the highest possible signal to phase noise ratio. Figure 8 shows the phase noise present on the output signal of the hp 5100A/5110A at 49 Mc. Figure 9 is a wave analyzer's approximation to the power spectrum of a 1 kc beat between two independent synthesizers individually multiplied to 8.75 gc. Figure 10 is the analyzer's response. The outer trace in each case is the same as the inner with 20 db gain applied. Notice that the spectral width observed is simply that of the analyzer.

The specified values for RMS Fractional Frequency Deviation at various averaging times and at various output frequencies represent the standard deviation of the short term frequency instability due to random noise. For example, the value given for one second averaging at an output of 50 Mc is 6×10^{-12}. This corresponds to an RMS or standard frequency deviation of 0.00030 cps. In other words, 68.3% of all observed frequency variations for measurement times of one second will differ from the carrier by less than plus or minus that amount. 99.7% of all frequency variations will differ from the carrier by less than ± 0.00090 cps. All statistical data are based on at least one hundred samples.

Modular Construction

Solid-state modular construction has been used throughout the 5100A/5110A. The modular concept enables the system to meet the stringent demands regarding spurious signals since the isolation that it affords minimizes spurious coupling. It also enhances serviceability. Careful design and quality control insure that all modules are interchangeable from one instrument to another.

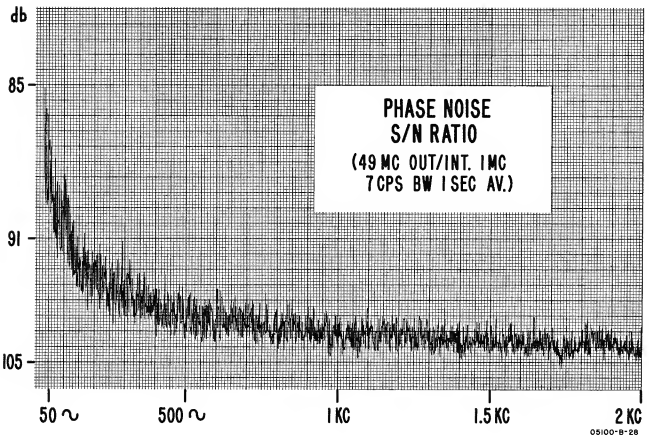


Figure 8

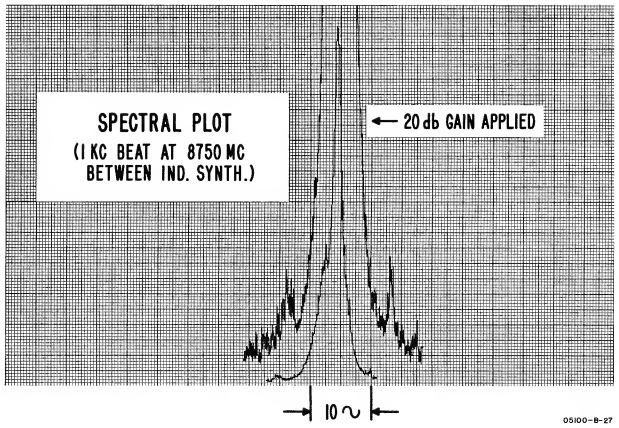


Figure 9

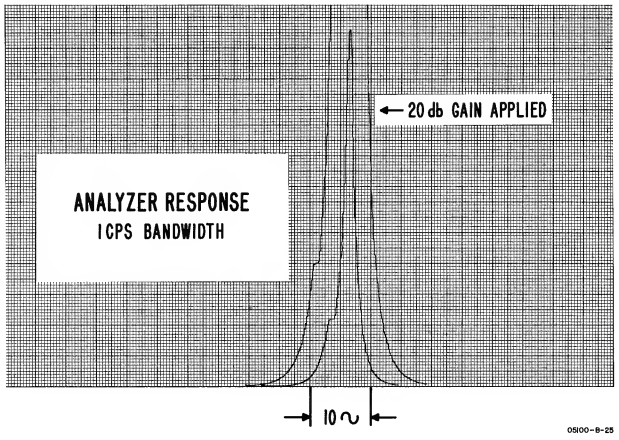


Figure 10

Specifications

5100A Frequency Synthesizer

Output Frequency: DC to 50 Mc.

Digital Frequency Selection: 0.01 cps through 10 Mc per step. Selection by front panel push-button or by remote switch closure. Any change in frequency may be accomplished in less than 1 millisecond.

Output Voltage: 1 volt rms ± 1 db from 100 kc to 50 Mc. 1 volt rms + 2 db, — 4 db from 50 cps to 100 kc, into a 50-ohm resistive load. Nominal source impedance is 50 ohms. 15 millivolts rms minimum open circuit from 100 kc down to DC, at separate rear output connector, source impedance of 10K ohm with shunt capacitance approximately 70 pf.

Signal-to-Phase Noise Ratio: Greater than 54 db in a 30-kc band centered on the signal (excluding a 1-cps band centered on the signal).

Signal-to-AM-Noise Ratio (Above 100 kc): Greater than 74 db in a 30-kc band.

RMS Fractional Frequency Deviation (With a 30-kc noise bandwidth):

Averaging Time	Output Frequency 1 Mc	5 Mc	10 Mc	50 Mc
10 milliseconds	3×10^{-8}	6×10^{-9}	3×10^{-9}	6×10^{-10}
1 second	3×10^{-10}	6×10^{-11}	3×10^{-11}	1×10^{-11}

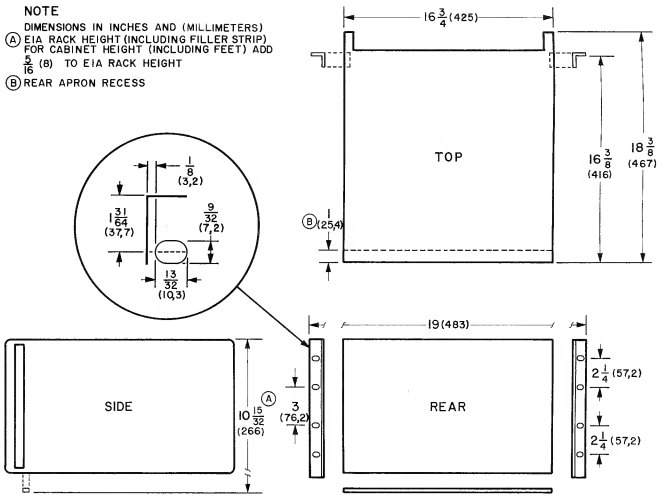
Spurious Signals: Non-harmonically related signals are at least 90 db below the selected frequency.

Harmonic Signals: 30 db below the selected frequency (when terminated in 50 ohms).

Weight: Net, 75 lbs. *(34 kg)*. Shipping, 127 lbs. *(58 kg)*.

► **Price:** $10,250.00 (requires 5110A).

Dimensions:



Note: When the 5110A Driver utilizes an external frequency standard, this will affect the stability and spectral purity of the output. Performance data stated above are based on internal frequency standard, also indicate Synthesizer contribution to overall performance with external standard.

Additional Data: Search oscillator provides continuously variable frequency selection with an incremental range of 0.1 cps through 1 Mc. Manual or external voltage (— 1 to — 11 volts) control with linearity of ± 5%.

Equipment furnished: 05100-6180 Decade Test cable, 05100-6066 Output cable, 05100-6157/8 cable assembly connects 5100A Synthesizer to 5110A Driver. Permits rack mounting of up to two 5100A's immediately above and/or below the 5110A Driver. A special-length cable assembly will be required for other mounting arrangements.

Special Features: If a special-length cable assembly is required, order spec C05-5110A. Specify configuration and length (max. separation 50 feet). Cable is supplied in five-foot sections only. Price: $40 per section.

5110A Synthesizer Driver

Output Frequencies: Provides 22 fixed frequencies to the 5100A Frequency Synthesizer; 3.0 through 3.9 Mc in 0.1 Mc steps (50 mv + 1, — 3 db) 30 through 39 Mc in 1 Mc steps, 24 Mc, and 3 Mc (100 mv ± 1.5 db), 50-ohm system.

1 Mc buffered output (1 volt ± 1.5 db into a 50-ohm resistive load) available at rear panel connector.

Internal Frequency Standard: 1 Mc Quartz Oscillator.

Aging Rate: Less than ± 3 parts in 10^9 per day.

Stability: As a function of ambient temperature: ± 2 x 10^{-10} per °C from 0°C to + 55°C.

As a function of line voltage: ± 5 x 10^{-11} for a ± 10% change in line voltage (rated at 115 or 230 volts rms line voltage).

Short term: Adequate to provide the 5100A performance noted above (1 x 10^{-11} rms for 1 second averaging on direct output for 30-kc noise bandwidth).

Phase Locking Capability: A voltage control feature allows 5 parts in 10^8 frequency control for locking to an external source. — 5 to + 5 volts required from phase detector (not supplied).

External Frequency Standard:

Input Requirements: 1 or 5 Mc, 0.2 v rms minimum, 5 v maximum across 500 ohms. Stability and spectral purity of 5100A Frequency Synthesizer will be partially determined by the characteristics of the external standard if used.

Additional Data:

Optional Features: The 5110A Synthesizer Driver is capable of driving up to four 5100A Frequency Synthesizers.

Option 02: Outputs for driving two 5100A Synthesizers. Price $125.00.

Option 03: Outputs for driving three 5100A Synthesizers. Price $235.00.

Option 04: Outputs for driving four 5100A Synthesizers. Price $345.00.

Note:

1. If Option 02-04 is selected, the additional outputs must be terminated in 50 ohms when not connected to a 5100A Synthesizer if full specified spurious performance is required.

   Accessory Available: 50 ohm BNC termination (hp) Stock No. 10510A. (22 required for each set of outputs not connected; e.g., maximum requirement would be 66 when Option 04 is selected but only one 5100A is being driven.) Price: $5.00 each.

2. A special interconnecting cable may be required for driving additional 5100A Synthesizers (see Special Features, 5100A above).

3. Small phase jumps (of about 0.1 radian in the worst case) will be experienced on one 5100A output when another 5100A, connected to the same 5110A, is switched from one frequency to another.

General

Operating Temp. Range: 0 to + 55°C.

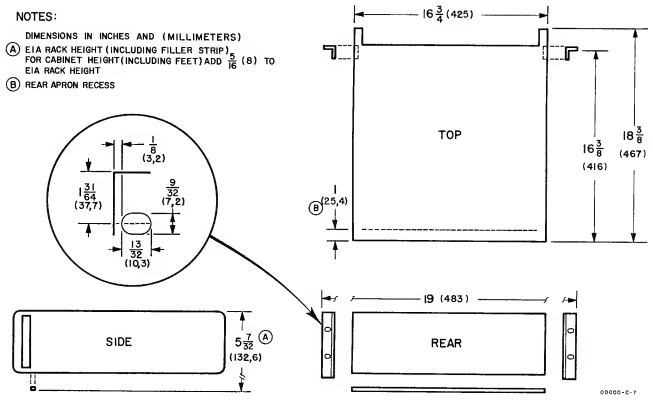
Interference: Complies with MIL-I-16910A[1].

Power: 115 or 230 volts ± 10%, 50 to 400 cycles, 35 watts each unit (independent supplies).

Weight: Net, 54 lbs. *(25 kg)*. Shipping, 60 lbs. *(27 kg)*.

► **Price:** $5,000.00.

Dimensions:



[1] Interference compliance with MIL-I-16010A requires that the 5100A and 5110A are connected by a low inductance path such as adjacent rack mounting.

Prices f.o.b. factory
Data subject to change without notice

4/14/64

► Indicates change from prior specifications